FOLDED CAMERA

PRIORITY INFORMATION

This application claims benefit of priority of U.S. Provisional Application Ser. No. 62/627,645 entitled "FOLDED CAMERA" filed Feb. 7, 2018, the content of which is incorporated by reference herein in its entirety.

BACKGROUND

Technical Field

This disclosure relates generally to camera systems, and more specifically to small form factor camera and lens systems.

Description of the Related Art

The advent of small, mobile multipurpose devices such as smartphones and tablet or pad devices has resulted in a need for high-resolution, small form factor cameras that are lightweight, compact, and capable of capturing high resolution, high quality images at low F-numbers for integration in the devices. However, due to limitations of conventional camera technology, conventional small cameras used in such devices tend to capture images at lower resolutions and/or with lower image quality than can be achieved with larger, higher quality cameras. Achieving higher resolution with small package size cameras generally requires use of a photosensor with small pixel size and a good, compact imaging lens system. Advances in technology have achieved reduction of the pixel size in photosensors. However, as photosensors become more compact and powerful, demand for compact imaging lens systems with improved imaging quality performance has increased. In addition, there are increasing expectations for small form factor cameras to be equipped with higher pixel count and/or larger pixel size image sensors (one or both of which may require larger image sensors) while still maintaining a module height that is compact enough to fit into portable electronic devices. Thus, a challenge from an optical system design point of view is to provide an imaging lens system that is capable of capturing high brightness, high resolution images under the physical constraints imposed by small form factor cameras.

SUMMARY OF EMBODIMENTS

Embodiments of the present disclosure may provide a folded camera that may, for example, be used in small form factor cameras. Embodiments of a folded camera are described that include two light folding elements (e.g., prisms) and an independent lens system located between the two prisms that includes an aperture stop and lens elements with refractive power mounted in a lens barrel. The prisms and lens system may collectively be referred to as an optical system. The prisms provide a "folded" optical axis for the camera, for example to reduce the Z-height of the camera. The lens system includes a lens stack including one or more refractive lens elements mounted in a lens barrel, and an aperture stop located at or in front of a first lens element in the stack. A first prism redirects light from an object field from a first axis (AX 1) to the lens system on a second axis (AX 2). The lens element(s) in the lens stack receive the light through the aperture stop and refract the light to a second prism that redirects the light onto a third axis (AX 3) on which a photosensor of the camera is disposed. The redirected light forms an image plane at or near the surface of the photosensor.

The shapes, materials, and arrangements of the refractive lens elements in the lens stack may be selected to capture high resolution, high quality images while providing a sufficiently long back focal length to accommodate the second prism. Parameters and relationships of the lenses in the lens stack, including but not limited to lens shape, thickness, geometry, position, materials, spacing, and the surface shapes of certain lens elements, may be selected at least in part to reduce, compensate, or correct for optical aberrations and lens artifacts and effects across the field of view. In some embodiments, arrangements of power distribution, lens shapes, prism form factors, and lens materials may be selected to ensure that embodiments of the lens system provide low F-number (e.g., <=2.4), 3× optical zoom, and high resolution imaging.

The lens system may be configured in the camera to move on one or more axes independently of the prisms. The camera may include an actuator component configured to move the lens system on (parallel to) the second axis (AX 2) relative to and independently of the prisms to provide autofocus functionality for the camera. In some embodiments, the actuator may instead or also be configured to move the lens system on one or more axes perpendicular to the second axis (AX 2) relative to and independently of the prisms to provide optical image stabilization (OIS) functionality for the camera. In some embodiments, one or both of the prisms may be translated with respect to the second axis (AX 2) independently of the lens system and/or tilted with respect to the second axis (AX 2) independently of the lens system, for example to provide OIS functionality for the camera or to shift the image formed at an image plane at the photosensor.

In some embodiments, the lens system may include a lens stack consisting of four lens elements with refractive power, in order from the object side to the image side of the camera: a first lens element with positive refractive power; a second lens element with positive refractive power; a third lens element with negative refractive power and an aspheric shape to correct chromatic aberration and field curvature; and a fourth lens element with a meniscus shape to correct field curvature and provide a low F-number.

In some embodiments, the lens system may include a lens stack consisting of five lens elements with refractive power, in order from the object side to the image side of the camera: a first lens element with positive refractive power; a second lens element with positive refractive power; a third lens element with negative refractive power and an aspheric shape to correct chromatic aberration and field curvature; a fourth aspheric lens element configured as an air-space doublet with the third lens element that assists in the aberration correction provided by the third lens element; and a fifth lens element with a meniscus shape to correct field curvature and provide a low F-number.

An aperture stop may be located in the lens system at the first lens element for controlling the brightness of the camera. Note that the power order, shape, or other optical characteristics of the refractive lens elements may be different in some embodiments, and some embodiments may include more or fewer refractive lens elements. In some embodiments, the folded camera may include an infrared (IR) filter to reduce or eliminate interference of environmental noise on the photosensor. The IR filter may, for example, be located between the second prism and the photosensor.